State of California
AIR RESOURCES BOARD

White Paper:

Summary of Staff's Preliminary Assessment of the Need for Revisions to the Zero Emission Vehicle Regulation

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List of Acronyms

AB ....Assembly Bill
ARB ....California Air Resources Board or the Board
AT PZEV .....Advanced Technology Partial ZEV Allowance Vehicle
BAU ....Business As Usual
BEV..............Battery Electric Vehicle
BOP ....Balance of Plant
CFO ....Clean Fuels Outlet regulation
CNG ....Compressed Natural Gas
CO_2e ....Carbon Dioxide emissions equivalent
CPUC...........California Public Utility Commission
DTI ....Directed Technologies Incorporated
EAER ....Equivalent All Electric Range
FCV..............Fuel Cell Vehicle
GDL ....Gas Diffusion Layer
GGE.............Gasoline Gallon Equivalent
GHG.............Greenhouse Gas
HDV ....Heavy Duty Vehicle
HEV ....Hybrid-Electric Vehicle
HICE ....Hydrogen Internal Combustion Engine
HOV.............High Occupancy Vehicle
ICE...............Internal Combustion Engine
IOU ....Investor Owned Utility
ISOR ....Initial Statement of Reasons
kW................Kilowatt
LCFS............Low Carbon Fuels Standard
LEV ....Low Emission Vehicle regulation
LEV III ....Future Low Emission Vehicle regulations, including criteria pollutant standards and greenhouse gas standards (formerly known as the Pavley Regulation, or Assembly Bill 1493)
$LiFePO_4$ ....Iron Phosphate Cathode Material (Battery)
Li Ion............Lithium Ion Battery technology
LMS ....Lithium Manganese Spinel
LVM ....Large Volume Manufacturers
MEA ....Membrane Electrode Assembly
MIT...............Massachusetts Institute of Technology
MMT.............Million metric tonnes
MSCD ....Mobile Sources Control Division
MWh ....Megawatt Hours
NCA ....Mixed oxide of nickel, cobalt, and aluminum
NCM.............Mixed oxide of nickel, cobalt, and magnesium
NEV ....Neighborhood Electric Vehicle
OEM.............Original Equipment Manufacturer
PEM ....Proton Exchange Membrane
PGM.............Platinum Group Metal
PHEV ....Plug-in Hybrid-Electric Vehicle

PUC ....Public Utilities Commission
PZEV ....Partial ZEV Allowance Vehicle
R&D ....Research and Development
SIE ....Spark Ignition Engine
SMR.............Steam Methane Reformation
SOC ....State of Charge
SOH ....State of Health
SULEV ....Super Ultra Low Emission Vehicle
TSD..............Technical Support Document
USABC ....United States Advanced Battery Consortium
U.S. DOE .....United States Department of Energy
U.S. EPA......United States Environmental Protection Agency
VMT ....Vehicle Miles Traveled
ZEV ....Zero Emission Vehicle

1. Introduction

Why is staff considering changes to the ZEV regulation?

Resolution 08-24
At the March 2008 Board Hearing, the California Air Resources Board (ARB or the Board) adopted modifications to the zero emission vehicle (ZEV) regulation as stated in Resolution 08-24[1]. According to Resolution 08-24, staff is to:

- Review the low emission vehicle (LEV), Pavley (GHG), and ZEV programs, keeping in mind the need to reduce criteria pollutant emissions, climate change emissions, and dependence on petroleum,
- Strengthen the ZEV program for model years 2015 and subsequent, focusing on ZEVs and enhanced advanced technology partial zero emission vehicles (Enhanced AT PZEVs),
- Ensure California is the center of ZEV commercialization development, and
- Return to the Board by the end of 2009.

To develop the framework for redesigning the ZEV regulation, staff undertook a review of the status of current ZEV technologies, included herein as Attachment A (Technical Support Document), and analyzed numerous pathways to illustrate how the passenger vehicle subsector can contribute to meeting California's long term 2050 greenhouse gas (GHG) reduction goal (Attachment B to this white paper). Additionally, staff conducted a review of current and possible future complementary policies, included as Attachment C, which could help the ZEV regulation achieve successful ZEV commercialization in California.

GHG Emission Reduction in California
In recognizing the potential for large, damaging impacts from climate change, California Governor Arnold Schwarzenegger enacted Executive Order S-03-05[2], requiring a reduction in state-wide GHG emissions to 80% below 1990 levels by 2050. In addition to the Governor's Executive Order, the State Legislature adopted and the Governor signed Assembly Bill (AB) 32, which has initiated programs to reduce GHG emissions across most sectors. The Board called for a redesign of the ZEV regulation to help meet the goals outlined in the Governor's Executive Order and in AB 32. As a result, the ZEV regulation needs to provide greater focus on achieving GHG emission reductions.

What does this mean for the future of the ZEV regulation?

As adopted in 1990, the ZEV regulation had the goal of helping meet the ambient air quality standard for ozone. The regulation envisioned one in every ten new cars sold would be a ZEV. Manufacturers developed ZEVs which were placed in demonstration fleets, and this continues today. They also developed

[1] ARB. California Air Resources Board (ARB). Resolution 08-24. March 2008.
[2] Executive Order. Governor Arnold Schwarzenegger. Executive Order S-03-05. June 2005

conventional gasoline engine vehicles and hybrid electric vehicles (HEV) with drastically lower smog-forming emissions that approach the zero emission goal. The Board modified the ZEV regulation several times to allow vehicle manufacturers to choose from this broader array of vehicle technologies in complying with the regulation. Although ZEVs (battery electric vehicles, or BEVs, and fuel cell vehicles, or FCVs) have not yet achieved a commercial status, very low emitting conventional gasoline vehicles (partial zero emission vehicles or PZEVs) and HEVs such as the Prius (advanced technology partial zero emission vehicles or AT PZEVs) have been commercialized and are being sold by most vehicle manufacturers in growing volumes. Over one million PZEVs and 250,000 AT PZEVs have been delivered for sale in California as a result of the ZEV regulation.

This situation suggests that the PZEVs and AT PZEVs no longer need to be part of a ZEV regulation whose goal is achieving commercialization of zero and near-zero emitting technologies, because these two technologies are now commercial. Commercial PZEV technology can be best considered in establishing revised hydrocarbon (HC), oxides of nitrogen (NOx), and particulate matter (PM) emission standards for the LEV program, whose purpose remains achieving the lowest smog-forming emissions possible, as needed to meet federal ambient air quality standards. AT PZEV technologies, principally the HEV, also have lower GHG emissions. This commercial technology can be considered in establishing more stringent GHG emission standards, which we plan to integrate into the LEV program. The revised LEV program, including more stringent standards for both smog and GHG emissions, will be considered by the Board in the second half of 2010.

What remains in the ZEV regulation are pre-commercial technologies, many of which have the potential to achieve very low GHG emissions, and thus contribute to meeting the Governor's 2050 GHG reduction target. The goal of the revised ZEV program should be to help move these demonstration, low GHG emitting technologies to commercialization, include FCVs, BEVs, and Enhanced AT PZEVs, which currently include plug-in HEVs (PHEV) and hydrogen internal combustion engine (HICE) vehicles. Following the successful mechanisms used to facilitate commercialization of PZEVs and AT PZEVs, the regulation would move ZEVs and Enhanced AT PZEVs from demonstration volumes, meaning hundreds (100s) and thousands (1,000s) per year, through pre-commercial volumes, meaning tens of thousands (10,000s) per year, to commercialization, meaning hundreds of thousands (100,000s) per year. Once this is achieved, the ZEV regulation would no longer be needed, and like the PZEV and AT PZEV technologies, they could be considered in setting future LEV performance-based emission standards.

How will this work within the LEV III Criteria Pollutant and GHG programs?
Starting in model year 2014, PZEV technologies would no longer be part of the ZEV program. Instead they would be considered in setting the stringency of the next criteria pollutant standard (hereafter, referred to as LEV III Criteria Pollutant). Starting in model year 2017, AT PZEV technologies would no longer be part of the ZEV program. Instead, they would be considered in setting the next greenhouse gas emission standard (hereafter, referred to as LEV III GHG). ARB staff is currently coordinating a series of studies to determine the potential GHG emission reductions and costs associated with wider spread use of HEVs, the main AT PZEV technology, especially when combined with light-weight vehicle structures. ARB staff will workshop both LEV III Criteria Pollutants and LEV III GHG program proposals during the first-half of 2010, with an initial statement of reasons (ISOR) presented to the Board for consideration in the summer or fall of 2010.

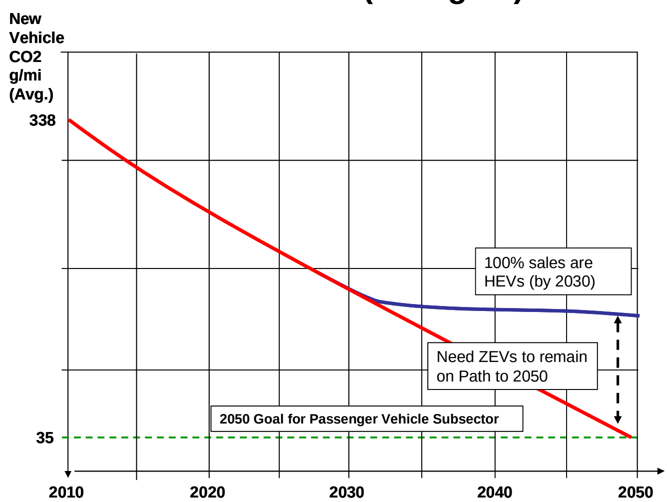
Will there be any criteria pollutant focus for the future ZEV regulation?
The Board has made significant reductions in criteria pollutants since the creation of the ZEV program in 1990. Resolution 08-24 requires staff to review the program keeping in mind the need for criteria pollutant emission reductions and GHG emission reductions. Most of the pre-commercial technologies which remain the focus of the ZEV program have the potential for extremely low criteria pollutants as well as very low GHG emissions. As these technologies become commercial, they will shift to being considered as part of the LEV standards, which will require that criteria emissions be near zero.

2. Meeting California's 2050 GHG Goal

What is needed in order to reach an 80% reduction in GHG emissions from 1990 levels by 2050?
The Governor's Executive Order establishes an overall 80% GHG reduction goal by 2050, compared to 1990 levels. In order to meet this goal, emissions from most sources of will need to be reduced substantially. Given that the transportation passenger vehicle subsector accounts for 28% of the state's GHG emissions today, it will be difficult to meet the 2050 goal unless this subsector achieves large reductions.[3,4,5] Graph 1 shows one path to meeting an 80% reduction in the passenger vehicle subsector.

[3] MIT. MIT Laboratory for Energy and the Environment. "On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions." LFEE 2008-05 RP, May 2008
[4] UC Davis. University of California, Davis (UC Davis) Institute of Transportation Studies. "Meeting an 80% in GHG Emissions from Transportation in 2050: A Case Study in California," Transportation Research Part D. 2009
[5] IEA. International Energy Agency (IEA). "Energy Technology Perspectives: Scenarios & Strategies to 2050." 2008

Graph 1: Reaching 80% GHG Reductions by 2050
New Vehicles (CO2 g/mi)



The red line in Graph 1 represents one path to achieving an 80% reduction in GHG emissions from the passenger vehicle subsector by 2050. To explore the importance of a specific technology in meeting the 2050 goal, the blue line coming off of the red line shows what kind of emission reductions can be achieved if by 2030 all new vehicles being sold were conventional hybrid vehicles such as the Prius. Conventional HEVs will not provide the reductions needed to reach 2050. This illustrates that other technologies that can achieve deeper cuts in GHG emissions will be needed to keep on the path towards the 2050 goal. Today these very low GHG emitting technologies are pre-commercial, and policies such as the ZEV program will likely be required to achieve commercialization in time to contribute the necessary emission reductions.

What is considered the passenger vehicle subsector's fair share of the overall reductions?

Staff's GHG analysis (Attachment B) assumes a 2050 target of 80% below 1990 passenger vehicle GHG emissions, which could be considered a "fair share" for the passenger vehicle subsector. We use this target in this paper to help frame the challenges ahead.[6] In reality, each sector will carry varying reduction levels to meet the state-wide average of 80%. A number of studies point out that GHG reductions in non-transportation sectors may be less costly, and therefore favored in a carbon market policy.[7,8] However due to the large contribution of passenger vehicles to overall emissions, it is unlikely that the overall GHG

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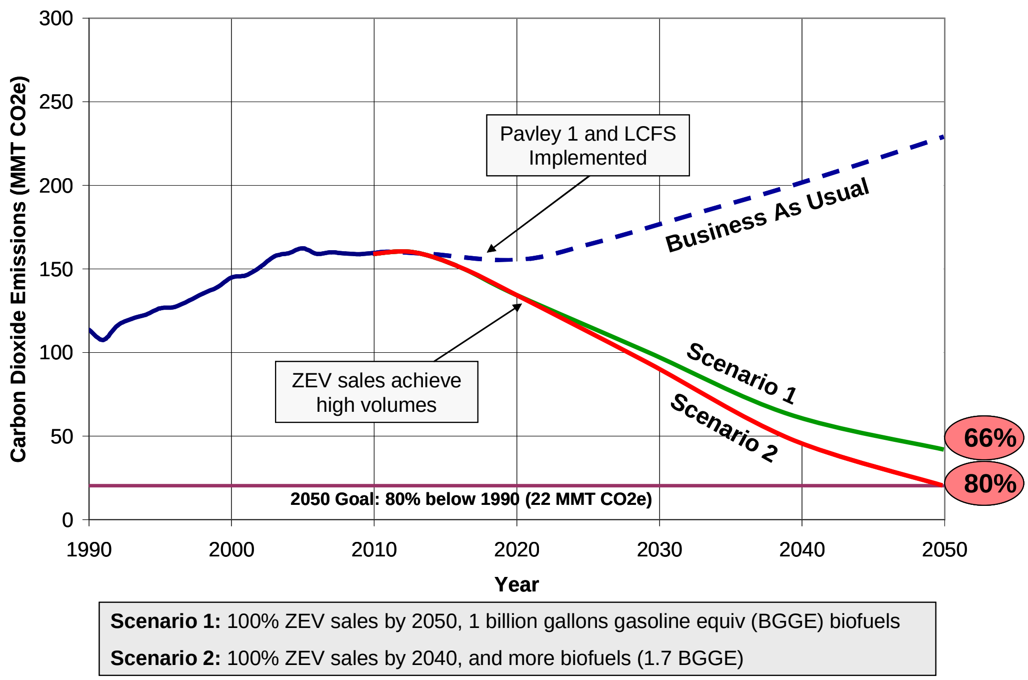
[6] 20% of 108.5 million metric tonnes (MMT) of carbon dioxide equivalent (CO2e) emissions
[7] McKinsey. McKinsey & Company. "Roads toward a low carbon future: reducing CO2 emissions from passenger vehicles in the global road transportation system." 2009
[8] IEA.

reduction goal can be met if passenger vehicle emissions are not reduced to near this subsector target.

What role can ZEVs play in contributing to the passenger vehicle subsector's long term GHG reductions?
Staff's analysis shows ZEVs will need to reach 100% of new vehicle sales between 2040 and 2050, with commercial markets for ZEVs launching in the 2015 to 2020 timeframe.[9]

Graph 2: ZEV Scenarios for Meeting 2050 GHG Goals



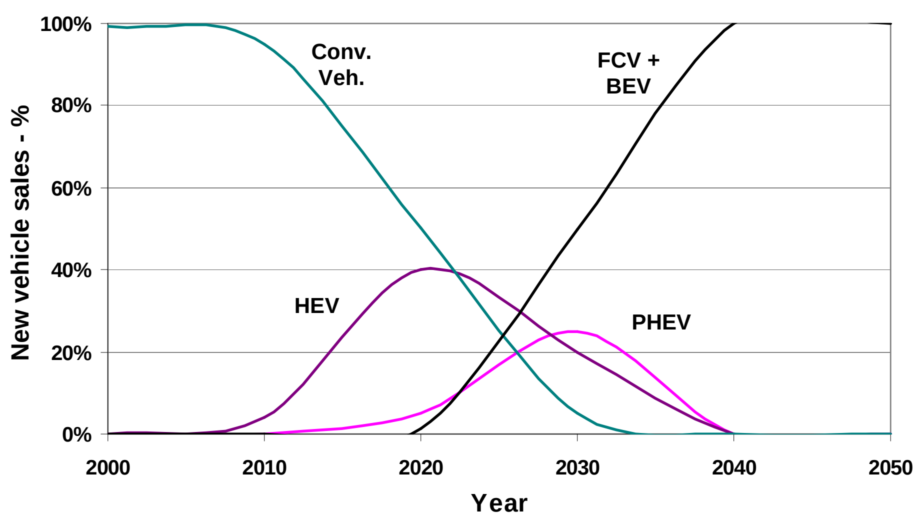
Graph 2 shows the GHG emissions between 1990 and 2050 for a "business as usual" (BAU) projection[10] and two scenarios, both assuming all advanced vehicle technologies are fully commercialized. Scenario 1 in this analysis achieves a 66% reduction in GHG emissions by 2050 using aggressive but plausible assumptions. This is shown by the green line and assumes ZEV sales reach a quarter of a million units annually by 2025 and become 100% of new vehicle sales by 2050. Scenario 2 was developed to show what would be required to achieve the full 80% GHG emission reduction goal. To achieve this, two key parameters were modified with more aggressive and uncertain assumptions. A steeper ZEV sales projection was simulated where ZEV sales reach half a million units by 2025 and are 100% of new vehicle sales by 2040. Additionally, the supply limit on biofuels was increased to 1.7 billion gallons gasoline equivalent (BGGE), where it was limited to 1 BGGE in Scenario 1.[11] The BAU projection

[9] See Attachment B for more details.
[10] The BAU projection does not reflect official ARB GHG inventory projections; it was developed solely for this modeling exercise and is purely hypothetical.
[11] Both cases have reductions in VMT per vehicle (20% below the VMT per vehicle projections for 2050

assumes the Pavley 1 Regulation and LCFS are both fully implemented, followed by a straight-line projection that assumes the vehicle fuel economy and fuel carbon intensity values from 2020 are fixed to 2050 as vehicle population grows ("2020 WTW Factor").[12]

How many ZEVs are needed to meet the goal? And when are they needed?
It takes decades for a new propulsion system to capture a large fraction of the passenger vehicle fleet for two reasons. First, new technologies require time for vehicle manufacturers to incorporate them on many or most models. For example HEVs have been sold in the US for a decade, yet they account for only 2% of new vehicle sales, and only in the past few years have a wider variety of HEV models been available. Second, once a new technology dominates the number of new models being offered for sale, it takes roughly 15 years for these vehicles to replace existing vehicles in the fleet. For example if the goal is to have most vehicles on the road in 2050 to be ZEVs, then most vehicles being sold in 2035 need to be ZEVs. Because of the first reason discussed above, this means that ZEV commercialization must begin well before 2035. Because of these considerations, it is important to accelerate[13] the introduction of low-carbon vehicle alternatives to ensure markets emerge between 2015 and 2020.

Graph 3: New Vehicle Sales, Passenger Vehicle Subsector[14]



Graph 3 shows the annual new vehicle sales projections for each type of vehicle technology in Scenario 2. The figure shows how conventional vehicle sales decline as advanced vehicle sales increase. HEV and PHEV sales also eventually decline as ZEV sales grow to maximize GHG reductions in the subsector.

[12] It is important to note that the exact BAU projection does not affect the scenario results given the 80% GHG goal is referenced to the 1990 emission level; they are shown purely for context.
[13] Accelerate advanced technology relative to how the automotive industry would introduce it if only complying with the vehicle GHG regulation (AB 1493).
[14] Scenario presented is the "Aggressive scenario"

Can any single ZEV technology provide all the necessary reductions?
Historically, the argument has been FCVs versus BEVs. This argument is irrelevant if an 80% GHG emission reduction by 2050 is the goal. In order to limit the risk in meeting California's long term goal, staff believes all ZEV technologies will be needed in order to achieve the necessary reductions for the passenger vehicle subsector. During private meetings with industry, most manufacturers showed all three technologies, FCVs, BEVs, and PHEVs as part of their long term product portfolios. Each technology is limited by various factors.

<u>FCVs</u>: that the fuel cell could potentially be used in all types and sizes of passenger vehicles and also achieve very low GHG emissions. However, most manufacturers see FCVs mainly used in mid-size sedan and larger sized vehicles, including trucks and SUVs.

<u>BEVs</u>: Some manufacturers believe BEVs will be able to fulfill 20-30% of the future fleet. Limited by vehicle range, weight, and cost, BEVs will more than likely be used in compact vehicle platforms for urban use where smaller batteries can be used. However, of the three vehicle technologies, all manufacturers agree that BEVs will play a key role in the 2050 fleet.

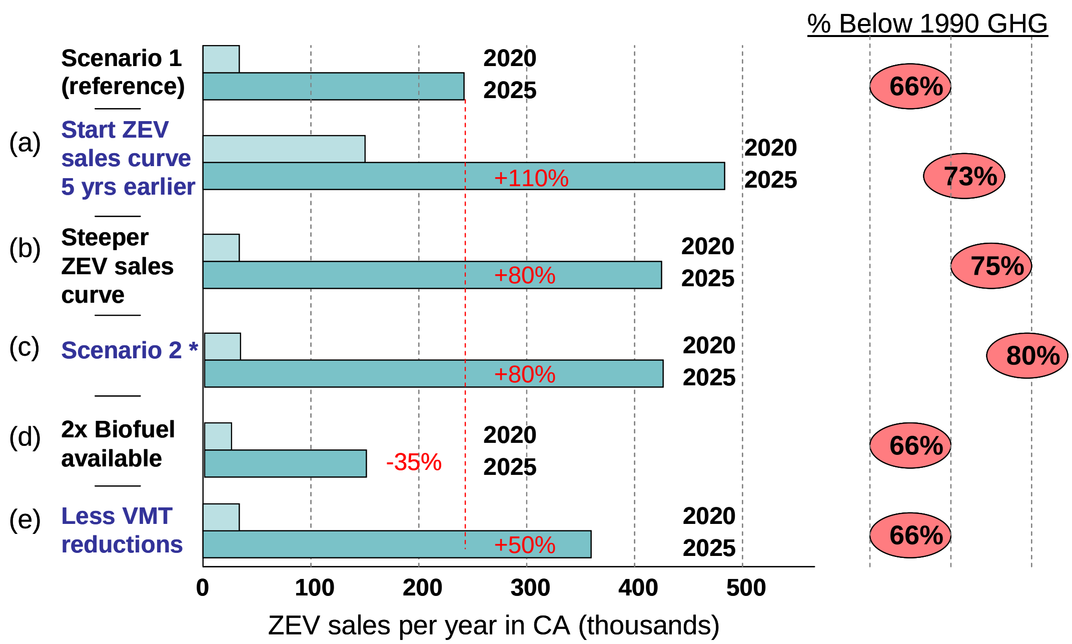
<u>PHEVs</u>: PHEVs could act as a stepping stone from conventional HEVs to full-function BEVs and FCVs. The primary advantages of PHEVs are the unlimited range provided by a conventional engine and modest all electric range allowing smaller battery packs. However, PHEVs with longer all electric range means significant battery cost and overall efficiency is compromised by the weight of both electric and conventional powertrains.

Future PHEVs will need to utilize advanced low carbon biofuels in order to deliver the large GHG emission reductions needed to meet the 2050 target. The availability of adequate volumes of advanced biofuels to fuel an all PHEV fleet is speculative. Thus PHEVs can reduce GHG emissions in the short and mid-term because of their use of electricity, but their ability to achieve the very low GHG emissions of BEVs and FCVs in the long term is uncertain as long as gasoline may be the fuel used when not operating on battery power. Graph 3 illustrates the role PHEVs may play under the assumption that the amount of low carbon biofuel available to passenger vehicles is limited to 1 billion gasoline gallon equivalent (BGGE) annually.

What are other important factors, in addition to ZEVs, that will help the passenger vehicle sector meet California's 2050 GHG goals?
Achieving an 80% reduction in the passenger vehicle subsector will require a broad mix of solutions. This includes reducing vehicle miles traveled (VMT) per vehicle, increasing vehicle fuel efficiency, increasing availability of low carbon fuels and electricity, and commercializing advanced vehicle technologies. Graph

4 below shows a sensitivity study from staff's analysis of how some of these factors impact achieving the 2050 goal and the needed ZEV annual sales in 2020 and 2025.

Graph 4: Sensitivity Study – Impact on ZEV 2020 and 2025 Sales



** Includes ZEV sales from (b) and an increase in biofuel usage (1.7 BGGE instead of 1 BGGE in Scenario 1)*

We use as a reference Scenario 1 shown in Graph 2 that achieves a 66% GHG reduction by 2050. We then vary assumptions regarding the ZEV sales projections, VMT per vehicle, and biofuel availability. The implications on the number of ZEVs that need to be sold in 2020 and 2025 are shown on the bar graph. We focus on 2020-2025 as this is the period that would be most affected by the changes in the ZEV regulation.

- **ZEV sales projections**: If the ZEV sales curve[15] to 2050 shown in Scenario 1 of Graph 3 is shifted 5 years earlier (a parallel shift with commercialization starting earlier and market saturation ending in 2045), GHG reductions in 2050 increase to 73% (case (a)). This shows that increasing early ZEV sales can make a difference. Alternatively, if the initial point of ZEV commercialization is not earlier (2020 sales the same as Scenario 1), but instead the rate of change of ZEV sales is increased so that ZEV sales reach the 100% level in 2040 instead of 2050, a 75% GHG reduction is achieved (case(b)).[16]

[15] The slope of the ZEV sales over multiple decades is highly uncertain. This analysis assumes an aggressive growth that is similar to assumptions in the NRC 2008c.
[16] Refer to Figure 12 in Attachment B for a graphical representation of the three ZEV sales projections.

- **Biomass supply**: Case (c) adds a higher availability of biofuels[17] (1.7 BGGE instead of 1.0) to the case (b) assumption of faster conversion to full ZEV sales. This combination achieves the 80% reduction goal (Scenario 2 in Graph 2). Returning to the lower rate of ZEV sales assumed in Scenario 1, doubling the biofuel supply available for passenger vehicles to 2 BGGE, increases the GHG reductions achieved in 2050 from 66% to 73%. Conversely, the number of ZEVs needed to be sold in 2025 could be reduced by 35% while still achieving a 66% reduction in GHG emissions by 2050 with this increased biofuel supply.
- **VMT reductions***:* If VMT per vehicle reductions only reach 10% (instead of 20%), ZEV sales in 2025 would have to be increased by 50% to maintain a 66% GHG reduction compared to Scenario 1.

What about PHEVs using ultra low carbon biofuels?
Some stakeholders think advanced low carbon biofuels may be the answer to reversing climate change in the transportation sector. One of staff's scenarios (not shown in Graph 4) shows that an 80% reduction in GHG emissions can be achieved with only PHEVs running on biofuels in the vehicle fleet. However, staff believes the amount[18] of advanced biofuels available to the passenger vehicle subsector in future years will be limited due to limits in feedstock and demands for the fuel by other sectors (e.g. aircraft). To limit the risk associated with depending solely on development and availability of future low carbon biofuels, staff believes the ZEV regulation should maintain a strong focus on ZEV commercialization in order to increase the odds of achieving California's long term GHG emission reduction goal.

3. Current status of ZEV technologies

What is the current status of FCVs?
While many technical barriers such as cold start difficulties, limited range, long refueling time, low power density, high stack weight and large stack volume have been overcome, challenges remain. High cost and insufficient durability are the two biggest challenges for fuel cell systems to meet U.S. DOE targets for FCV commercialization. The U.S. DOE estimates the 2009 cost of a fuel cell system to be $61/kW (if produced in high volumes)[19], which is approximately a 16% reduction in one year from $73/kW in 2008. The fuel cell system cost estimate includes the 80 kW_{net} direct hydrogen PEM fuel cell stack and balance of plant (BOP) at high production volumes (500,000 units per year). It is important to note that the U.S. DOE cost estimate excludes the hydrogen storage tank. The U.S. DOE 2015 fuel cell system target is $30/kW and was set to drive down fuel cell system costs in order for fuel cell systems to be competitive with

[17] All scenarios assume biofuels are blended into gasoline and diesel at varying levels and consumed by any vehicle technology with a combustion engine (conv. Vehicles, HEVs, and PHEVs).
[18] 1 billion gallon gasoline equivalent (BGGE) limit on biofuels available to passenger vehicle subsector.
[19] U.S. DOE 2009a. Spendelow, Jacob and Marcinkoski, Jason. "DOE Hydrogen Program Record #9012". October 7, 2009.

gasoline internal combustion engines. Accordingly, the U.S. DOE estimates that automotive engines cost between $25-35/kW.[20] As a result, 2009 fuel cell system cost (at high volumes) is approximately two times the cost of an internal combustion engine. All industry stakeholders agree that continued fuel cell research and design need to occur in order to reach commercial viability. Most automakers that are aggressively pursing FCVs believe the U.S. DOE targets are reasonable and several companies believe FCV commercialization can be achieved before U.S. DOE cost targets are reached. Additionally, automakers aggressively pursuing FCV technology – Daimler, Ford, General Motors, Honda, Hyundai/Kia, Toyota and alliance Renault SA and Nissan – issued a joint letter of understanding in September 2009 regarding development and commercialization of FCVs. The auto manufacturers strongly anticipate that from 2015 onwards, a significant number –"a few hundred thousand units over the initial products' lifecycles of FCVs could be commercialized".[21] For more information regarding the status of FCV technology and FCV commercialization, please see Attachment A, staff's Technical Support Document.

What is the current status of automotive battery technology?
Large Li Ion battery development and production capacity buildup are proceeding at the pace necessary to meet the PHEV and BEV deployments required by the Board's ZEV Regulation through 2014. These batteries are now described as "pre-commercial" by most large automakers moving forward with PHEV and BEV deployments prior to 2014.

What is the current status of BEVs and PHEVs?
Since 2007, PHEV development programs have expanded and are now underway at every large auto company. Automakers with the earliest development programs have further expanded those 2007 programs and have progressed to pre-production prototype evaluations.

While PHEVs looked promising even back in 2007, the Expert Panel[22] was unable to find any significant BEV development activity at any large auto manufacturer. Within a span of two years, staff believes that there are now BEV development programs at every medium and large auto manufacturer. Although some of this activity is admittedly driven by ARB's ZEV regulation, this is a remarkable shift in only two years. The automakers with the largest and most significant of these near-commercial BEV development programs claim that meeting the California ZEV Regulation has become a secondary consideration, and that long-term commercial success and corporate environmental

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[20] U.S. DOE 2009b. United States Department of Energy. Office of Energy Efficiency and Renewable Energy. "Hydrogen, Fuel Cells & Infrastructure Multi-Year Research, Development and Demonstration Plan". Updated April 2009.

[21] Green Car Congress 2009. Green Car Congress. "Automakers Issue Joint Statement in Support of Commercial Introduction of Fuel Cell Vehicles from 2015 Onward". September 9, 2009. http://www.greencarcongress.com/2009/09/automakers-fcv- 20090909.html

[22] At a 2003 Board Hearing, the Board directed that an independent panel of experts (Panel) be convened to report on the status of ZEV technologies and their readiness for commercialization. The Panel's findings were presented to the Board in May 2007.

stewardship are now their primary motivations. Steady progress in automotive Li Ion battery performance is believed to have helped enable this shift in automotive technology.

While there has been extraordinary progress with electric vehicles, every automaker has cautioned ARB staff that there are extraordinary challenges to be overcome in order to sell and support large numbers of PHEVs and BEVs in California, and that these challenges will require considerable and coordinated efforts on the part of federal, state, and local governments to make electric vehicles a reality. No automaker has stated that current designs, or even next generation Li Ion batteries, will achieve sufficiently low cost to make them competitive with conventional vehicles without government incentives and/or tax credits. Several automakers do, however, believe that Li Ion battery systems will evolve sufficiently to allow automakers to sell cost competitive PHEVs and BEVs sometime prior to 2020, and that these electric-fueled vehicles will play a key role in automaker efforts to meet both corporate and California vehicle emissions reduction objectives. For more information regarding the status of BEV technology and BEV and PHEV commercialization, please see Attachment A, staff's Technical Support Document.

How does current ZEV status compare with what may be needed to meet long term GHG emission reduction goals?

In June 2009, staff sent out a formal survey to all automotive manufacturers, fuel cell manufacturers, and battery suppliers requesting information regarding current status of ZEV technologies.[23] Staff met with every large volume manufacturer in person to discuss survey results as well as future ZEV policy. Manufacturers indicated much progress had been made since the 2007 review; however more time is needed before ramping up to commercial volumes.[24]

The challenge facing the Board is determining when ZEV technologies can be ready for commercialization, what is their likely rate of uptake into the fleet (in the absence of a regulatory requirement), and deciding if this is consistent with achieving the Governor's 2050 GHG reduction target. Based on staff's analysis of what needs to occur to achieve this goal, it appears likely that market forces alone will not be sufficient. In the absence of regulation, it is likely that the conversion of conventional models to ZEV technologies will be slower than needed, which will also slow the uptake of these technologies into the fleet. In addition, fuel infrastructure needs and market pull policies will likely be needed to support the initial entry of these technologies into the market. This suggests to staff the necessity of a regulatory requirement to identify the need for ZEVs and provide some degree of certainty to investors in these technologies, combined with industry/government efforts to establish fueling infrastructure and provide consumer incentives to purchase these vehicles in their initial years of sales.

[23] See Appendix 1 and 2 in Attachment A for the full survey and participating stakeholders.
[24] Survey findings and staff's assessment can be found in Attachment A.

Staff believes this approach would increase the chances of achieving the GHG target on time.

4. Future ZEV Policy

What about using a performance standard rather than a mandate?
In recognizing the important role that ZEVs can play in meeting California's future GHG reductions and air quality goals, staff believes that some version of a ZEV regulation should be maintained. The current ZEV program requires specified numbers of ZEVs be sold each year by larger vehicle manufacturers. The numbers are relatively low through 2014, and are designed to accelerate the pre-commercial phase of vehicle development. Based on manufacturer announcements, staff believes there will be several BEV and PHEV models offered in much higher, commercial volumes by 2015. Vehicle manufacturers have also suggested that commercial volumes of FCVs could be available by 2015 if fueling infrastructure is provided. Once many models are available and the technology is well established in the marketplace, a performance standard (e.g. a more stringent GHG tailpipe standard) can be used accelerate and increase the use of the technology in the marketplace. This has historically been the mechanism used in nearly all ARB regulations.

Technologies such as ZEVs will likely require a slower transition to high volume production. During early commercialization the number of ZEVs that can be produced is too low to materially affect the average emissions of all vehicles a manufacturer sells. Thus a performance standard can not provide a reasonable assurance that ZEVs will be produced in necessary volumes to provide a launch of the technology in the marketplace. (In other words, it would be easy for a vehicle manufacturer to lower the average emissions of all cars it sells rather than produce a small volume (e.g. a few percent of sales) of ZEVs). Thus staff believes the ZEV program should include specific regulatory mechanisms to reduce the risk of early ZEV market failure and reduce market barriers to ZEV commercialization (e.g. fueling infrastructure and higher initial costs). This would provide a higher degree of assurance that commercial volumes of ZEVs are offered for sale through the point where sales are sustainable along a path that could achieve the 2050 GHG goal. This of course assumes that remaining technical issues have been resolved, as staff believes they will be by 2015.

What are the options for modifying the ZEV regulation in model years 2015 and beyond?
Below are three policy alternatives staff would like to further develop for the 2010 rulemaking, based on the above discussion:

<u>Policy Alternative 1: ZEV Regulation Continues</u>
The ZEV regulation has been modified six times since its creation in 1990 to reflect the status of emerging zero and near-ZEVs. The program has demonstrated the technical viability of BEVs, provided for the successful

commercialization of PZEVs, helped launch the early markets for conventional HEVs, and supports the continuing development of FCVs. The program will simplify itself, a stated desire of the Board, as early credit multipliers, PZEV and AT PZEV allowances, and other early incentive allowances cease between model years 2011 and 2015. By trimming down and focusing the regulation on ZEVs and Enhanced AT PZEVs, the regulation could work as originally conceived: X-percent of a manufacturer's fleet must be ZEVs.

This structure would require a certain percentage of a manufacturer's new sales to be ZEVs and Enhanced AT PZEVs in a given year or years, similar to the current ZEV regulation. The required percentage of sales that are ZEVs would increase to the point where it is clear that the technology is more than a niche product, and growing, sustainable sales are likely. Staff would also consider modifications to the following in each of the alternatives:

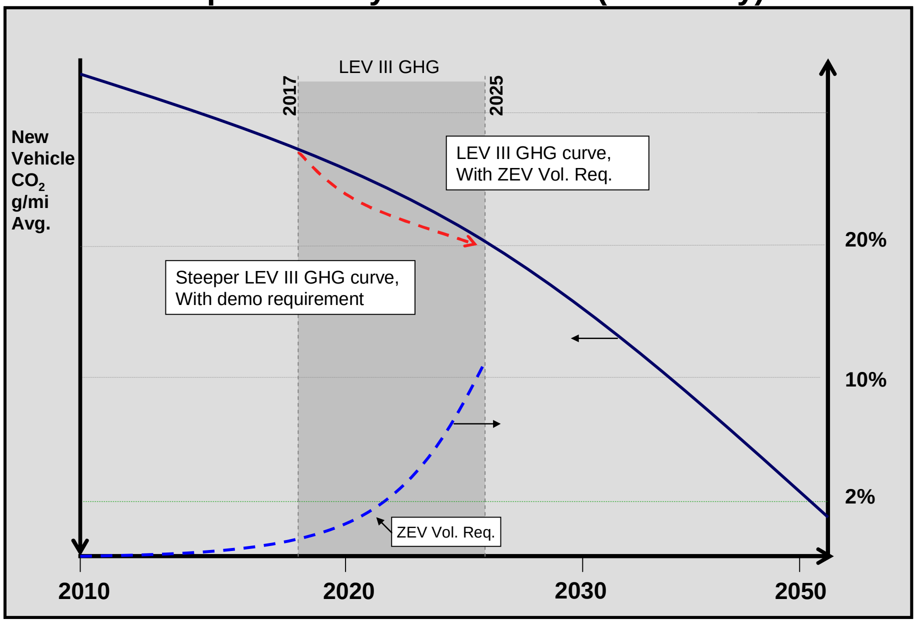
- Credit values and structure
- Travel provision
- Credit banking

Many manufacturers, including Toyota, Nissan, and General Motors, have announced plans to deploy PHEVs and BEVs between 2010 and 2014. This is an indication that the original structure of the regulation is working to place ZEVs on California's roads. Additionally, keeping a similar regulatory structure will continue to assure commercialization includes full function ZEVs that have the potential for a growing and sustainable market share, and provide a diverse mix of ZEV technologies, which appears to be necessary to achieve a large reduction in GHG emissions by 2050.

Policy Alternative 2: More Flexibility of When ZEV Commercialization Begins

In this alternative, manufacturers would have a choice to opt-in to some form of a ZEV mandate, or to continue with demonstrations of ZEVs. If a manufacturer were to elect a ZEV mandate, it would also to comply with the LEV III GHG performance standard (hereafter referred to Option 1). If a manufacturer were to elect to participate in a demonstration ZEV program (i.e. produce much lower volumes of ZEVs), the manufacturer would need to comply with a stricter LEV III GHG performance standard (hereafter, referred to as Option 2). These two options are illustrated in Graph 5 below. The dashed blue line illustrates the ZEV mandate for manufacturers that chose Option 1, and the corresponding solid blue line would be the required fleet average GHG standards for all vehicles sold.

Graph 5: Policy Alternative 2 (Flexibility)



For those choosing to continue with demonstration rather than pre-commercial volumes of ZEVs, more effort to reduce fleet wide GHG emissions would be required. Option 2 may be attractive to manufacturers that believe additional battery or fuel cell development for their vehicles is needed, or by vehicle manufacturers with exceptionally low emitting conventional vehicles that want to avoid the cost of introducing larger volumes of a new technology. In either case, ZEV technology would continue to develop and mature, whereas a straight performance standard would provide no assurance that ZEV technology would continue towards commercialization. Staff believes that this alternative could put California on the path to meet its 2050 GHG emission reduction goals in the passenger vehicle subsector, but may lead to delayed development of ZEV technologies and increased risk of slipping off that path in later years. .

Are there any concerns about either of these policy alternatives?
Policy alternative 1 is not a redesign of the program, and could fall into the same pattern and pitfalls as past ZEV regulations. Policy alternative 2 runs the risk that the number of ZEVs will not reach an adequate level of commercialization in order to successfully achieve the 2050 GHG target. Staff will weigh these concerns with the benefits of each alternative throughout the next year of regulatory development.

Where do we go from here?
Revised LEV III Criteria Pollutant and LEV III GHG standards will be presented for the Board's consideration in late summer 2010. Revisions to the ZEV will be proposed shortly after the Board's decision on LEV III. This will ensure PZEVs

and AT PZEVs are firmly part of new adopted performance standards, and can be dropped from the ZEV program requirements.

It is unclear at this time what LEV III requirements will be proposed since staff is currently developing these standards. Based on the performance standard required through LEV III GHG, ZEV staff will determine if the LEV III GHG standard is in line with the path to 2050. If ZEV staff determines further emission reductions are needed to put the passenger vehicle subsector on a path to 2050, staff may propose a stronger ZEV-specific mandate. If the LEV III proposal is inline with the path to 2050, staff will consider regulatory structures, like Option 2, which give more flexibility to industry. Both LEV III staff and ZEV staff will workshop regulatory proposals starting in quarter one of 2010.

5. Complementary Policies

What is the current status of ZEV fueling infrastructure?
Today, infrastructure for both BEVs and FCVs could be considered demonstration or experimental. For hydrogen, current vehicle needs are minimally being met and the stations to be built by the end of 2010 will meet the needs of the 2011 FCV fleet. More stations will be required beyond 2011.

For BEVs, a minimal charging infrastructure exists, but the connectors are not compatible with vehicles planned for introduction in the near future, so upgrades will be needed. The majority of charging will occur at home and off-peak charging will remain essential to achieving low-carbon electricity fuel. In response to OEM announcements about deploying significant numbers of BEVs in the next five years, the California Public Utility Commission (CPUC) has begun a rulemaking to understand and overcome the many barriers to developing charging infrastructure.[25] Staff will be conducting a review of electric infrastructure policies and will provide a California-specific infrastructure plan to the Board in the first half of 2010.

How much hydrogen infrastructure is needed in the near term to meet expected ZEV demand?
The California Fuel Cell Partnership (CaFCP) released its Action Plan in February 2009, which detailed OEM FCV rollout plans during the 2009 through 2017 timeframe as well as recommendations for meeting hydrogen demand and station placement though 2012.[26] The Action Plan included Table 1 below, a summary of OEM's near term FCV deployment plans, assuming no barriers to hydrogen fuel availability.

[25] CPUC. California Public Utilities Commission (CPUC). Order Instituting Rulemaking to Consider Alternative-Fueled Vehicle Tariffs, Infrastructure and Policies to Support California's Greenhouse Gas Emissions Reductions Goals. August 2009.
[26] CaFCP. California Fuel Cell Partnership. "Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead". February 2009.

Table 1: FCV Deployment in California

	2009	2010	2011	2012-2014	2015-2017
Total CA	193	370	712	4,307	49,600

The CaFCP determined between 50 and 100 hydrogen fueling stations will be needed in the next eight years in order to support the projected number of FCV in California.

What are the options for establishing hydrogen infrastructure?
ARB staff believes a multi-pronged approach is needed to ensure sufficient hydrogen infrastructure. This approach has three key elements, which are discussed in the following paragraphs:

1. Financial Incentives
2. Regulatory Incentives
3. Hydrogen Station Mandate

Are financial incentives sufficient to get hydrogen infrastructure?
In the next two years, hydrogen fueling infrastructure needs may be sufficiently supported by stations currently funded and under development, and by monetary incentives for additional stations. However, the current amount of AB 118 funding proposed by the California Energy Commission (CEC) for hydrogen station deployment is only enough to build half the additional stations needed. Additional funds will be needed to further support and spur on hydrogen infrastructure.

Staff believes financial incentives alone will not provide sufficient assurance that enough hydrogen infrastructure will be in place to meet near and mid-term demand for hydrogen fuel. Also, financial incentives are not sufficient to take hydrogen infrastructure from the current demonstration stage to full commercialization of larger stations with high capacity.

If money alone can not ensure hydrogen infrastructure, what other incentives may work?
ARB could use existing regulatory tools to provide incentives to fuel providers. One possibility may be modifying the Low Carbon Fuel Standard (LCFS) to provide additional incentives for installing fueling infrastructure for very low carbon fuels such as hydrogen. This incentive could accelerate the installation of fueling stations at no financial cost to the state. Caps could be placed to limit how many extra credits a fuel provider may earn in order to minimize any loss of GHG reduction from the LCFS.

This approach, like the monetary incentives, may not guarantee installation of adequate fueling infrastructure. A “stick” approach, rather than a “carrot”, also needs to be considered.

What about a hydrogen station mandate?
The third approach to establishing hydrogen infrastructure would be mandate on fuel transportation suppliers. This could be accomplished by modifying the existing Clean Fuels Outlet (CFO) regulation, originally adopted by the Board to address the possible need for alcohol and natural gas fueling. As currently written, the CFO requires alternative fueling stations to be built after a certain number of alternative fueled vehicles enter the fleet. The number of hydrogen vehicles required to trigger a mandate is currently set too high to effectively support initial placement of FCVs, and the current regulation does not apply to electricity as a transportation fuel.

The CFO could be modified by lowering the vehicle numbers that activate the regulation and shifting the compliance burden upstream to the fuel providers. In theory, this approach could both work to support near-term hydrogen and other fuel infrastructures. One downside is that mandated stations may not be able to compete for public funding under current statutory restrictions.

What is likely the best formula for success in getting sufficient hydrogen infrastructure?
ARB staff believes a multi-pronged approach of monetary incentives, regulatory incentives, and a regulatory mandate will be needed to effectively support hydrogen infrastructure. Continued near-term funding is critical to meet more immediate infrastructure demands while increasing the state's renewable hydrogen production. Regulatory incentives, such as an LCFS multiplier, could encourage some energy companies to choose ZEV fuels over other lower-cost options and, combined with a revised fuel station mandate, could offer a more cohesive compliance structure for motor vehicle fuel providers.

What is being done to guarantee ZEV fuels continue to provide a GHG benefit?
Senate Bill 1505, chaptered in 2006, requires that all state funded transportation hydrogen must be 33 percent renewable and produce 30 percent less GHG well-to-wheel. This requirement will extend to all transportation hydrogen once the statewide annual throughput reaches 3,500 metric tons.

For electricity, Executive Order S-21-09 directed ARB to use its authority under AB 32 to adopt a regulation consistent with the 33 percent renewable energy target established in Executive Order S-14-08 by July 31, 2010. ARB is working with the PUC and the CEC to ensure that this regulation builds upon the Renewable Portfolio Standard Program and regulates all California load serving entities. In addition, all load serving entities are expected to reduce their climate change emissions under California's proposed Cap and Trade Regulation with its firm and declining emissions cap. Finally, the CPUC rulemaking discussed earlier is focusing on rate structures that encourage charging during off-peak hours when current excess renewable energy resources, such as wind, can be better utilized.

None of staff's proposed regulatory alternatives guarantee ZEV market pull. Why is this?
Complementary policies (Attachment C) are important to ensuring success of ZEV commercialization. The sole purpose of the ZEV regulation is to put vehicles on the road in appropriate timeframes. State and Federal incentives for consumers will be important in near-term ZEV deployment, with some version of monetary incentives like feebates[27] likely needed in the longer term. Staff will continue to assess the status of market pull complementary policies and need for additional incentives as it develops its proposed amendments to the ZEV regulation.

6. Backburner Issues

What about the PZEV 150,000 mile, 15 year warranty? Does this disappear when PZEVs leave the ZEV regulation?
The extended warranty requirement is tied to the ZEV regulation as an alternative to producing higher volumes of ZEVs. Thus once the PZEV requirements are removed form the ZEV regulation, the extended warranty can no longer be required. To preserve the benefits of the extended warranty, staff is considering providing extra emission credits under the LEV III Criteria Pollutants program to those manufacturers who chose to offer an extended warranty. Also, staff is considering making changes to the Environmental Performance Label that would place manufacturer warranty information clearly on every new car sold. Changes to the warranty provisions will be addressed as part of the proposed changes to the LEV regulation in 2010.

What is the role of PHEVs in the future ZEV regulation?
Staff believes PHEVs will be an effective technology to help reduce GHG emissions, especially in years prior to 2050. In the interim years, substantial PHEV sales will be needed to help achieve deep GHG emission reductions. They are efficient (very low GHG emissions) when operating on grid-provided electricity. However, it remains unclear how often over the vehicle's life gasoline will be used in lieu of electricity. Thus their ability to achieve the deep GHG reductions required to meet the 2050 target is uncertain unless the availability of very low carbon biofuels is assured. Therefore, PHEVs will likely continue to receive less credit than a ZEV in the future ZEV regulation.

What about everything else?
Many stakeholders are interested in potential modifications to specific current ZEV regulatory provisions. These include ZEV credit values, treatment of intermediate volume manufacturers, the travel provision, and transportation

[27] Feebates are a fiscal policy that set a benchmark for greenhouse gases (CO_2e) for new vehicles. For more information, see Attachment C.

system credits. Staff plans to address concerns related to these items during the rulemaking process in 2010.

7. Conclusion and Recommendations

What is staff recommending to the Board?

1. The focus of the ZEV regulation should be shifted to address GHG emission reductions as well as criteria pollutants emission reductions.
2. An important new goal for the ZEV program should be to help assure the transformation to very low carbon-emitting vehicles occurs in the timeframe necessary to meet the Governor's 2050 target of an 80% reduction in GHGs compared to 1990 levels.
3. The upcoming revision to the ZEV regulation should help assure the successful launch of commercial ZEVs in the next decade, which appears needed to meet the 2050 GHG target.
4. PZEVs, now a part of the ZEV regulation, are commercial, and can be removed from the ZEV regulation (effective in 2014). Their emission benefits are appropriately considered in next summer's revision to the LEV criteria emission standards.
5. AT-PZEVs, now a part of the ZEV regulation, are commercial, and can be removed from the ZEV regulation (effective in 2017). Their emission benefits are appropriately considered in next summer's revision to the LEV GHG emission standards.
6. The proposed structure and stringency of the revised ZEV program will depend in part on the Board's decision on establishing more stringent GHG standards for the overall fleet, next summer, and how well it places on the path to meeting an 80% reduction in GHG emissions by 2050.
7. The staff intends to further evaluate incentive and regulatory policies that can assure adequate fueling infrastructure is available for to support the commercialization of ZEVs.
8. The staff will also evaluate the adequacy of incentives to encourage purchase of ZEVs, and will recommend to the Board what complementary policies best support implementation of the ZEV program.

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